1969

Double-puff eyelid conditioning technique to examine CS-UCS intensity relationships

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A DOUBLE-PUFF EYELID CONDITIONING TECHNIQUE TO EXAMINE CS-UCS INTENSITY RELATIONSHIPS

By

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B.S., Ball State University, 1966

Presented in partial fulfillment of the requirements
for the degree of

Master of Arts

UNIVERSITY OF MONTANA

1969

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Date Aug 29, 1969

8-26-69

ACKNOWLEDGMENTS

The author wishes to express his gratitude to the members of his thesis committee, Dr. Charles Allen, Dr. Frances Hill, Dr. Peter Hemingway, Dr. Andrew Lee, and Dr. Thomas Johnson, with particular thanks to Dr. Allen for his encouragement and guidance.

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I. INTRODUCTION

Much of the classical conditioning research has traditionally been dedicated to studying the effects of stimulus intensity manipulations. Despite this extensive investigation, however, controversies remain as to the role of CS (conditioned stimulus) and UCS (unconditioned stimulus) intensity variables (Walker, 1960; Burstein, 1967).

Certainly the vital role of the CS in conditioning has long been suspected. Pavlov (1928), for example, stated that ". . . the magnitude of the conditioned reflex is determined . . . by the amount of energy transmitted to the cortex . . ." (p. 387), and also noted that increasing intensities of the CS result in more rapid conditioning. Similarly, Miller (1951) stated his belief that increasing intensities of cue stimulation account for heightened responsiveness in the organism.

The results of attempts to empirically confirm these statements have been conflicting, however, particularly in the case of classical eyelid conditioning research. Most notable of those studies indicating a direct relationship between CS intensity increments and conditioned responding are those of Barnes (1956), Beck (1963), Brown (1942), Hovland (1937), Hull (1949), Razran (1956), and Walker (1960). No relationship was seen in studies by Carter (1941), Grant & Schneider (1948; 1949), and Lipkin & Moore (1966).

The contradictory nature of these findings has led several investigators to offer explanations. Walker (1960) noted that those analyses in which response strength was measured during acquisition of the conditioned response (CR) were successful in demonstrating a positive relationship between CS intensity and the strength of the response; whereas those relying on extinction data typically were not.

Grice & Hunter (1964) commented that the type of experimental design might well have influenced the detection of intensity effects on performance. They compared CS intensity effects on the acquisition of a CR using a within-subjects design (each S received both intensities of CS during acquisition) and a random groups design (Ss assigned only one intensity--two groups of Ss used). Their results indicated that CS intensity effects were more likely to be detected in the former design.

The evidence is more conclusive as to the effects of UCS intensity on performance during acquisition. Several studies (Passey, 1948; Ross & Spence, 1960; Spence, 1953; Spence, Haggard, & Ross, 1958) support the belief that acquisition performance is increased by UCS intensity increases. The recent controversy on this matter engendered by the work of Burstein (1965; 1967) seems to have led to additional evidence (Spence & Platt, 1966; Suboski, 1967) in support of a strong UCS-performance relationship.

In addition to those studies which have examined either CS or UCS intensities singly, are those which have manipulated both CS and UCS intensities for the purpose of ascertaining the effect of the relationship of these intensities on the course of conditioning. The first such effort was that of Walker (1960), who reported that CS intensity reliably influenced response strength during acquisition. She noted, however, that CS intensity seemed to affect the short latency responses, both "voluntary form" and conditioned responses, as opposed to those of longer latency. These latter responses were clearly more influenced by the UCS intensity. Also of interest was the fact that there were indications that CS intensity had a more pronounced effect on performance under a strong UCS than under a weak one. Extinction data showed no CS effect.

Horn (1961) in a somewhat similar study which used three CS (tone) intensities and four UCS intensities found only UCS intensity effects with no significant interaction between CS and UCS. A possible explanation for the lack of a significant CS effect and CS-UCS interaction might be offered in terms of the small number of Ss employed (8 Ss/cell) and the comparatively short acquisition phase (only 60 conditioning trials were given).

The most recent research effort which sought to manipulate both CS and UCS intensities was that of Beck (1963). She examined the effect of these variables along with that of emotionality as defined by the Taylor Manifest Anxiety Scale scores (Taylor, 1953). High and low anxiety Ss were used with various UCS intensities. In this study the CS was a within-Ss variable; that is to say that of the 80 paired presentations of tone and puff given each S during acquisition, 40 were with a weak CS and 40 were strong. Beck reported that all three variables were positively related to CR acquisition. Most notable of these results was the CS effect on both long and short latency responses. This finding seemed to run counter to the results of Taylor (1954) and Walker (1960), who obtained a CS effect only for short latency responses. Beck (1963) speculated that owing to the fact that the CS was a within-Ss variable, the significance of its effect might well lie in a contrast effect or adaptation level phenomenon.

Clearly a problem implicit in studies such as those of Walker (1960), Horn (1961), and Beck (1963) has been one of how to relate the stimulus intensities utilized for the CS to those employed as the UCS. Since traditionally the stimuli have been of different modalities (e.g. tone and puff), the relationship of a 5 psi (lbs/sq. in.) nitrogen puff delivered to the Ss' cornea to that of a 60 db tone, for example, was clearly problematical.

A logical solution to this problem was to use stimuli of the same modality for CS and UCS. For this reason, the study performed and reported herein utilized corneal air puffs as both CS and UCS. That is to say, a puff-puff pairing was used instead of the more typical light-puff or tone-puff combinations.

Several objections might be voiced to this procedure, which admittedly represented a significant departure from the techniques historically employed in American conditioning experiments.

The first of these problems is derived from the misconception of the role of the CS in conditioning. Classical conditioning has traditionally been defined as the procedure whereby an initially neutral stimulus (the CS) comes to elicit a response formerly given only to another stimulus (the UCS), through repeated temporal pairings of the two stimuli. It is notable that the stimuli typically employed as CSs, particularly in American studies, have been light or tone presentations (Razran, 1957). The primary reason for utilizing such stimuli is that they have a low probability of evoking the unconditioned response (UCR) prior to acquisition.

One might reasonably question, however, whether these supposedly "neutral" stimuli are, in fact, truly neutral. Pavlov (1957, p. 201) was among the first to notice that these stimuli were capable of evoking observable responses in the organism before training, namely that involved in "paying attention" to the stimulus, or the orientation reflex, as he chose to call it. Certainly it seems logical that if an organism does perceive a stimulus, it is in some was responding to it, albeit implicitly.

With these facts in mind, the reader is asked to simply consider the CS as a stimulus which signals the occurrence of the second air puff. It will be seen that the fact that the CS elicits its own UCR does not lessen its effectiveness as a signal.

It was expected that through pairing the two air puffs, the first puff (the CS) would come to elicit not only its own UCR, but a second blink (a CR) with a latency such that it overlapped the occurrence of the second stimulus (the UCS). As Figure 1 illustrates, the response originally evoked by the CS was modified to include two responses

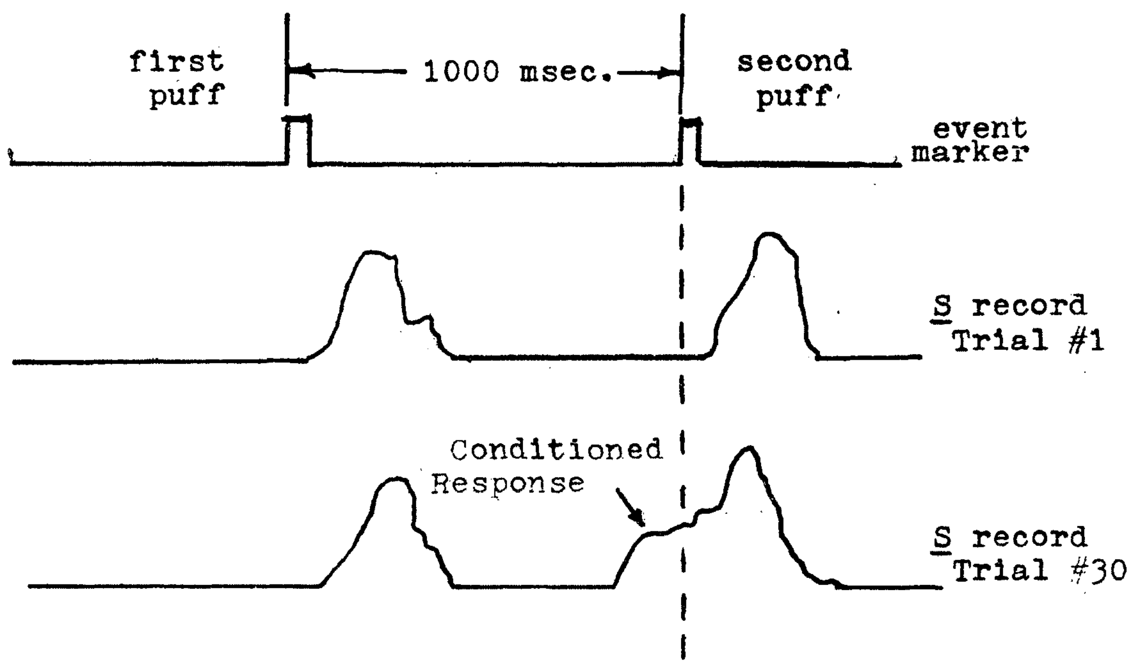

Fig. 1.-- Form of CR with Double-puff Technique

or blinks. Viewed in this light, the apparent differences between this procedure and that typically employed in classical conditioning seem somewhat more reconcilable.

The historical precedents of the proposed study date back to the work of Yerofeeva (1922; 1921). These Russian studies showed that using a combination of shock and food reward as the CS and UCS respectively, salivary conditioning could be demonstrated in dogs. Asratyan (1961), too, reports on several other Russian conditioning studies which have made use of two different "unconditioned stimuli" pairings in an effort to establish "two-way conditioned reflex connections." Additionally, Razran (1957) reports the use of aversive conditioned stimuli in the work of Marukhanyan (1954), Fedotova (1954), and Fedorov (1933).

The precedent for pairing <u>like</u> or identical stimuli comes first from the work of Wendt (1930). He used two successive blows to the patellar tendons of his <u>S</u>s and successfully conditioned a knee jerk in one leg to a blow struck on the other knee. Similarly, in two studies designed to assess the effect of certain drugs on leg flexion conditioning in dogs, Pronko & Kellog (1942) and Headlee & Kellog (1941) employed shock-shock pairings.

<u>Theoretical Implications</u>

There are several theories which have direct bearing on the investigation reported herein. The first of these is that of Pavlov (1927), who maintained that the UCS must be more "biologically significant" than the CS if conditioning were to be established. Supporting his theory are several investigations including the work of Yerofeeva (1911). This investigation demonstrated that by using a shock as the CS and meat powder for the UCS, salivary conditioning could be achieved in the dog, but only if the animal had been on a sufficient food-deprivation schedule. Pavlov interpreted this finding by noting that only by depriving the animal of food did the UCS become more "biologically significant" than the shock.

If one then equates Pavlov's notion of biological significance with aversiveness, i.e. air puff intensity, one might expect that unless the UCS were more intense than the CS, little or no conditioning would result. Assuming sufficient UCS dominance, however, increases in either CS or UCS strength would lead to greater performance in acquisition.

Razran (1957), like Pavlov, holds that the UCS must dominate the CS before conditioning can occur. His emphasis, however, is not on the importance of UCS intensity, but rather on UCR magnitude (primarily a function of UCS intensity and duration). He charges that the UCR-magnitude, CS-intensity ratio, along with these two factors singly, greatly affect the acquisition of the conditioned response.

The implications of Razran's theory, then, are that "within certain limits on the CS and UCR-magnitude continua," increases in CS and UCS intensities will lead to heightened acquisition performance. This relationship will apply, however, only on the ascending portion of a hypothesized gradient of conditioning efficacy, which peaks at some optimal ratio of CS-UCS intensity and falls off rapidly on either side.

If one seeks to apply Hullian theory to the proposed investigation, several interesting predictions emerge. First from Hull's work (Hull, 1949) with rats on an instrumental conditioning task there emerged the concept of stimulus intensity dynamism (V). This factor, defined by Hull as the "motivational potentiality of stimulus intensity," would apply to the cue stimulus or CS in the proposed experiment and would clearly increase with CS intensity increases. The V factor was said by Hull (1951) to combine multiplicatively with habit strength to affect performance.

Also, according to Hull, the UCS intensity would be a drive variable. Since the factors V and D (drive) are multiplied, both CS and UCS are seen as combining to produce higher conditioning levels with increasing stimulus intensities.

The predictions from this theoretical position are then that either CS or UCS intensity increases will contirbute singly to the level of acquisition. By virtue of the *V* X *D* product, however, both these variables should, by combining in a multiplicative manner, interact and thereby cause response-rate change. It is notable that no provision is made that the UCS must "dominate" the CS and that the direct relationship between CS and UCS intensity and conditioning levels presumably holds for all intensities within the limits posed by perceptual threshold and organic tolerance.

The final theoretical formulation to be considered is that of adaptation level theory as propounded originally by Helson (1964) and extended to reinforced learning situations by Bevan and Adamson (Bevan, 1963a, 1963b). This reinforcement pooling model has had considerable success in treating reinforcing agents as psychophysical stimuli, that is by scaling them on a continuum ". . . having neutral or indifferent regions and in being subject to both series and anchor effects . . ." (Helson, 1964, p. 449). According to this model, organisms average such stimuli over time, thereby creating adaptation levels or indifference points. The distance of the reinforcer from the adaptation level determines its effectiveness. Depending on whether the reinforcing stimulus is perceived as being above, below, or equal to the AL, its reinforcing characteristics are said to be either strong, weak, or moderate, respectively.

Applying these concepts to this study, it seems reasonable that both stimuli, CS and UCS, together over trials would create a norm or adaptation level. The distance the UCS departed from this level would determine its reinforcing effectiveness, or the performance level attained.

Briefly, then, the following study represented an attempt to employ a new conditioning technique, that of utilizing two, temporally paired, corneal air puffs as stimuli. This technique was employed for the purpose of attempting to ascertain the effects of CS and UCS intensity combinations on the acquisition of the conditioned eyelid response.

II. METHOD

Subjects

The Ss were 180 student volunteers from the introductory psychology course at the University of Montana. These individuals were screened prior to their participation to ensure that none had previous eyelid conditioning experience.

Apparatus

The experiment made use of two adjoining rooms. The smaller room in which all Ss were conditioned was semi-soundproof and brightly illuminated. In it were two chairs, one in each section of an E-shaped cubicle. The Ss sat facing the open end of the cubicle and approximately four feet from a wall covered with white acoustical tile. A speaker was positioned in the corner of the room through which white noise and taped instructions were delivered.

The E's room contained all of the equipment necessary for delivering the stimuli and recording the responses. The trials were initiated by a tape programmer which actuated a series of Hunter Model 100C timers controlling sequencing and event durations. These timers energized the Dynograph amplifier-recorder (Type 542) and the Skinner

Electric solenoid valves. The CS and UCS were delivered from separate tanks of water-pumped nitrogen. The stimulus intensities were regulated by means of two tank-mounted Victor two-stage pressure valves. Static pressure readings (mm. of Hg.) were taken from 1/4 inch (inside diameter), open end, U-shaped mercury manometers. These readings represented the pressure at the regulator outlet. Responses were recorded by means of two Giannini micro-torque potentiometers which were connected to the amplifier-recorder. The potentiometers and air hose nozzles were contained in an assembly which was mounted on an adjustable headband. Instructions and white noise were delivered by means of a tape recorder. Additionally an intercom system allowed Ss to communicate with E.

Procedure and Design

Each S was randomly assigned to one of 15 groups (n=12). Comprising these groups were nine experimental conditioning groups and six pseudoconditioning control (P-C) groups. See Figure 2.

The Ss assigned to the experimental groups received 80 temporally paired presentations of one particular combination of puff intensities. These paired presentations (commonly termed acquisition trials) consisted of two puffs of appropriate intensity separated by an interstimulus interval of 1000 msec. A mean intertrial interval

Second Stimulus

First Stimulus	W	M	S
W	W-W	W-M	W-S
M	M-W	M-M	M-S
S	S-W	S-M	S-S

Note: dash (-) indicates temporal pairing; (≠) means not paired

W= weak stimulus (100 mm. Hg)

M= medium stimulus (215 mm. Hg.)

S= strong stimulus (300 mm. Hg.)

Experimental Groups

Control

W≠W	M≠M	S≠S	W≠M M≠W	M≠S S≠M	W≠S S≠W

Fig. 2.-- Basic Design of the Experiment

(ITI) of 15 seconds was employed by randomly varying the ITI from 10 to 20 sec.

The pseudoconditioning control groups received the same number of stimulus presentations in a random, unpaired sequence. These groups were run in an effort to assess the contribution of the <u>pairing</u> of the two stimuli (as occurring in the conditioning groups). The stimuli were delivered at the same rate as for the experimental groups (approximately 8 stimuli per minute). The time interval between the stimuli was randomly varied between 5, 7 1/2 and 10 sec.

The pseudoconditioning controls used are seen in Figure 2. Separate tallies were kept of the number of responses which were elicited by each of the two intensities used in the group. It is notable that six groups of <u>S</u>s provided an adequate control against which the performance of nine experimental groups could be assessed. Three of the six P-C controls (M≠W, S≠W, and S≠M) served a dual function in that they provided control for two experimental groups. For example, the M-W control yielded a baseline response level for both the M-W and W-M experimental groups. The responses given to the weak stimulus in the P-C control served as a baseline of response for the W-M group. Similarly, the responses given to the medium intensity puff in the same group served as a standard against which conditioning was assessed in the M-W experimental group. The three additional P-C controls ($W \neq W$, $M \neq M$, and $S \neq S$) each applied only to one experimental group. For these P-C groups the mean of the data provided to each stimulus (of the same intensity in these cases) was utilized.

The particular weak and strong puff intensities utilized in this experiment were selected with regard to previous eyelid conditioning literature. The weak (W) stimulus of 50 mm. Hg. represented an intensity which was sufficiently strong that <u>S</u>s would not adapt to it. The strong stimulus (S) of 150 mm. of Hg. represented an intensity near the top of the range of those typically administered, yet one which was not sufficiently strong to be regarded as painful. The intermediate (M) intensity was selected by a psychophysical scaling procedure (see Appendix), which endeavored to select a stimulus which was perceived as being half-way between the weak and strong stimuli in intensity. The scaling pilot data indicated that this value was approximately 105 mm. Hg. and this intensity was used for the medium stimulus throughout the experiment.

<u>Response Definition</u>

The use of the comparatively long trace conditioning interval of 1000 msec. posed certain problems in arriving at a criterion for delineating the conditioned response. Because of the possibility that the experimental variables might be differentially affecting the latency of the conditioned responsed produced, all responses occurring after the initial UCR to the first puff were considered. Pilot data indicated that most such responses were initiated at least 400 msec. following CS onset. The remaining criteria utilized were those advanced by Boneau (1958) and Prokasy, Ebel and Thompson (1963) which score a response as a CR only if it occurs before and overlaps the UCR (to the UCS).

The final criteria then for the scoring of a conditioned response were:

(a) a minimum pen deflection of at least one mm.

(b) a minimum onset latency of 400 msec.

(c) a response of sufficient duration so as to overlap the UCR to the UCS

The same criteria were applied in scoring the responses given by Ss in the pseudoconditioning groups.

Experimental Procedure

The Ss (two/session) were greeted by E and were seated in the semi-soundproof room. The headband assembly (potentiometer and air nozzle) was adjusted to S's head. The wire from the potentiometer was fastened to the right eyelid just above the eyelash by means of a small piece of tape. The amplifier-recorder was then actuated and certain adjustments made to ensure a distinct response record would be obtained. The tape-recorded "neutral set" instructions were then played for Ss (see text below). The E then asked if there were any questions. The air nozzles were then oriented into a position approximately 1/2 inch from S's right cornea. The E then advised S that if at any time during the course of the study he should feel the need to contact E (i.e., to adjust the headband, etc.) all he need do was to simply state this need verbally and E would be right in to make the necessary adjustments. The E then left the room closing the door behind him. The tape-recorded white masking noise was then switched on and adjusted in volume to a previously determined sufficient level, the programmer was actuated, and the system began delivering the stimuli. At the completion of the experimental session (of approximately 24 minutes duration), Ss were unhooked from the apparatus, thanked for their participation, and dismissed.

Instructions

Please listen carefully to the following instructions. In this experiment we are interested in studying human reflexes. More specifically, we are going to record the reflex movements of your eyelid. In order to elicit these reflexes you will receive puffs of air to your eye. Since we are interested in your reflexes, there is nothing in particular you have to do. That is to say do not purposely blink your eye, but at the same time do not try to inhibit your blinking. Just try to respond naturally. It is important, however, that you remain alert. Please sit upright in your chair and do not lean your head against the wall behind you. Also, please do not try to communicate with your fellow subject. Throughout the experiment you will hear a rather loud noise coming from the speaker in the corner. This noise is merely used to mask out equipment sounds in the experimenter's room and you will become accustomed to it in a few minutes. Please do not try to make adjustments on the apparatus after the experiment has begun. In summary, then, sit upright in the chair and let your reactions take care of themselves.

Criterion for Eliminating Ss

No Ss were eliminated in this study as "non-conditioners." Ss who gave more than 20% sustained responses (as defined as an eyelid closure to the first puff which was sustained until after the second puff), however, were eliminated. These Ss were generally evenly distributed among all experimental groups.

Dependent Variable

The number of conditioned responses given in a block of ten trials served as the dependent variable for all analyses. This quantity was expressed as either percent CRs or as the probability of a response occurring (decimal form). Sustained blink trials were ignored in this computation.

III. RESULTS

A 3 X 3 X 8 (CS X UCS X trials) analysis of variance with repeated measures along the trials dimension was performed on the experimental group data. As anticipated, there was a significant trials main effect, $F(7, 693) = 4.94$, $p < .01$, and UCS by trials interaction, $F(14, 693) = 2.76$, $p < .01$. The data (see Table I and Figure 3) revealed no other statistically significant main effects or interactions.

A similar analysis, a 3 X 3 X 4 (CS X UCS X trials) with repeated measures along the last four trial blocks, revealed only a significant UCS effect, $F(2, 99) = 3.37$, $p \leq .05$. See Table I.

The analysis of the control data was made considerably more restricted by the lack of independence among certain of the groups, i.e., six groups of <u>S</u>s contributed data for nine control groups. Those groups which were independent, W≠W, M≠M, and S≠S, were analyzed in a simple subjects by treatments analysis of variance based on the mean probabilities over the last four trial blocks. The results were non-significant, $F(2, 33) = 1.43$, $p < .25$. See Figure 4 and Table II.

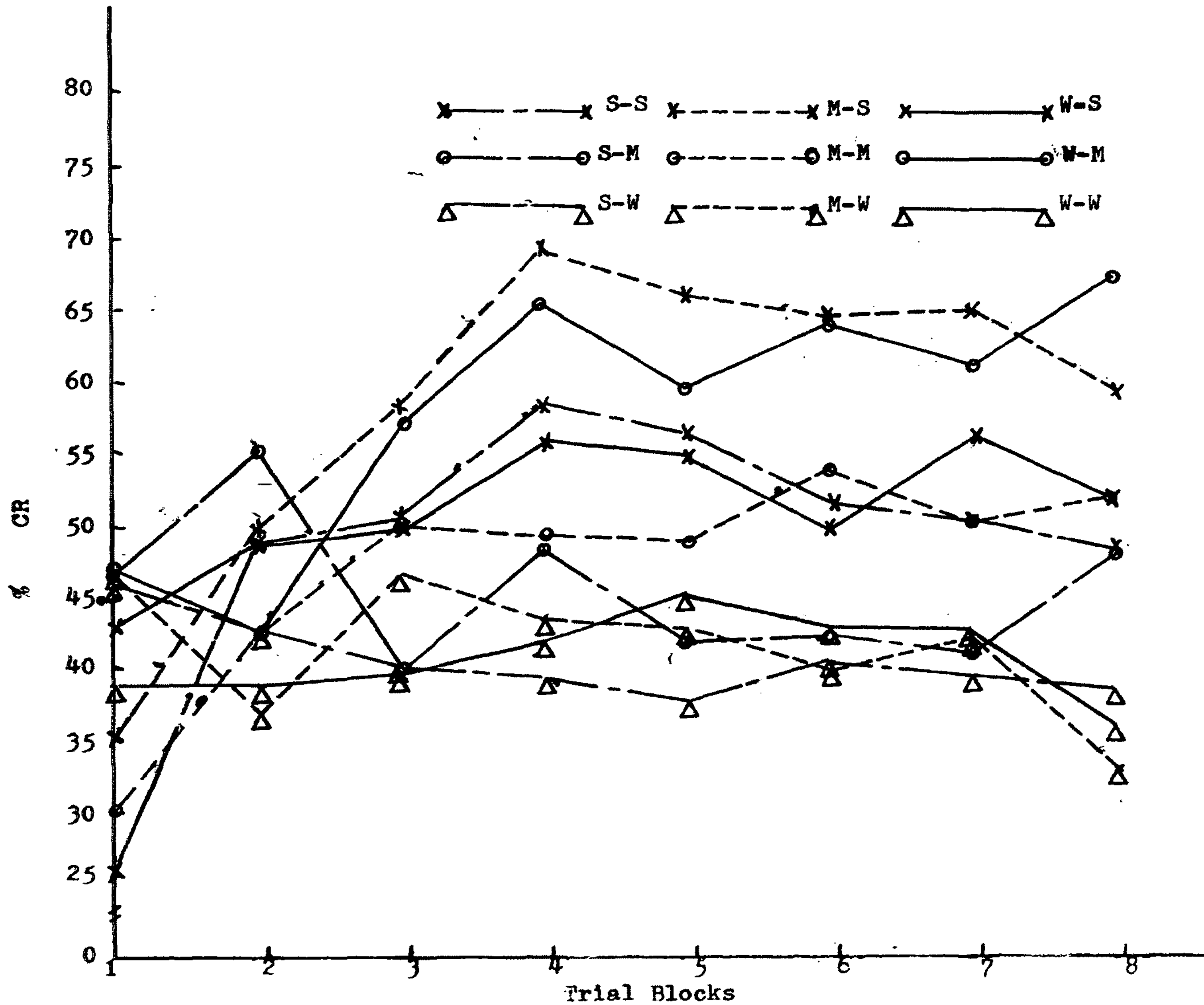

Fig. 3-- Experimental Group Data (non-adjusted)

TABLE I

MEAN RESPONSE PROBABILITIES AND RANKINGS FOR EXPERIMENTAL GROUPS

	W-W	W-M	W-S	M-W	M-M	M-S	S-W	S-M	S-S
Based on 8 trial block means	.409	.579	.510	.414	.471	.582	.400	.456	.487
Ranking	2	8	7	3	5	9	1	4	6
Based on last 4 trial block means	.557	.842	.704	.525	.681	.845	.521	.579	.687
Ranking	3	8	7	2	5	9	1	4	6
Adjusted 4 trial blocks	.162	.437	.346	.214	.174	.353	.072	.106	.170
	3	9	7	6	5	8	1	2	4

TABLE II

MEAN RESPONSE PROBABILITIES FOR CONTROL GROUPS

W+W	M+W	W+M	W+S	S+W	M+M	M+S	S+M	S+S
.250	.180	.190	.182	.319	.337	.281	.329	.346

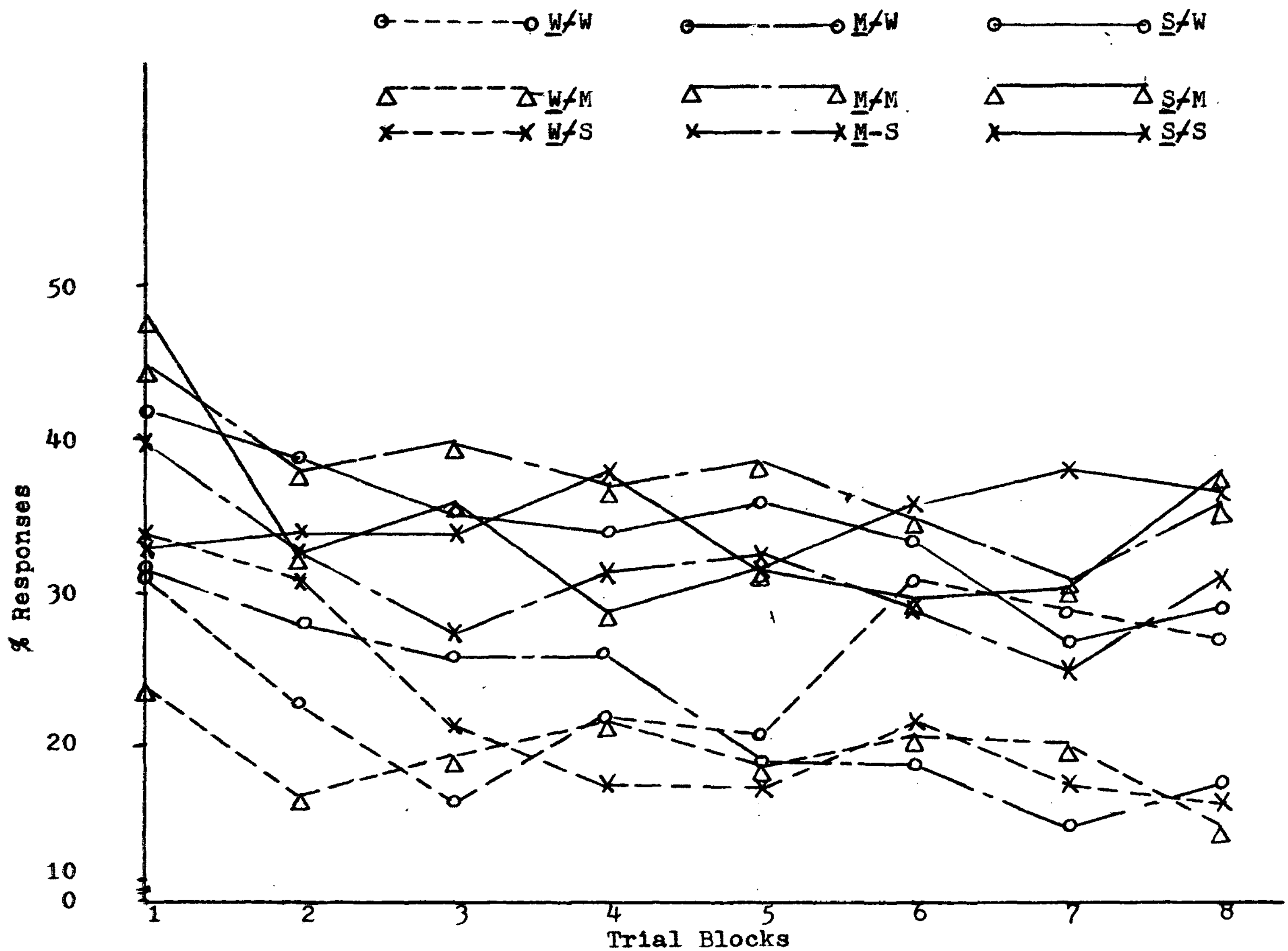

Fig. 4-- Control Group Data

Because of the interest in evaluating whether conditioning had indeed occurred utilizing the aversive CS, a series of six analyses were performed which enabled the comparison of each experimental group against its appropriate control. To ensure that the individual comparisons (post-hoc) were not affected by Type I errors, the conducting of these comparisons was contingent on the occurrence of a significant F-ratio in the six overall analyses. Each of these analyses was a 3 X 2 X 8 design with repeated measures over the trials dimension. One analysis was devoted to a comparison of all those experimental groups which had in common a given stimulus intensity as either CS or UCS, with their appropriate controls. There was, for example, an analysis which was devoted to those experimental groups which had a strong stimulus in the second (UCS) position. This analysis included the experimental groups W-S, M-S, and S-S, along with their appropriate controls, W-̸S, M-̸S, and S-̸S. The dimensions of these 3 X 2 X 8 analyses were then: (a) the other stimulus dimension (e.g., in the case of the example cited above a CS dimension), (b) the experimental-control dimension, and (c) the trial blocks dimension. As Table III shows, a statistically significant F-ratio was obtained for the experimental-control main effect in each of the six analyses, indicating only that at least one of the

TABLE III

F-RATIOS FOR SIX ANALYSES*

	S as 1st	S as 2nd	M as 1st	M as 2nd	W as 1st	W as 2nd
Main effect E-C dimension	F= 4.47	F= 21.20	F= 13.67	F= 15.27	F= 37.18	F= 8.67

*Critical F= 4.00 with df= 1, 66; $p < .05$
Critical F= 7.08 with df= 1, 66; $p < .01$

experimental groups differed significantly from its control.

As was mentioned previously, however, the real importance of the preceding significant F-ratios was that their occurrence justified the conducting of the post-hoc individual comparisons, i.e., the comparing of each experimental group against its appropriate control group. Each experimental group and its control appeared in the context of two of the preceding six analyses; therefore, two such individual comparisons were made, each utilizing the mean square error term from the appropriate overall analysis. The findings based on the results of an F-test statistic (Winer, 1962, p. 208) are reported in Table IV and show that only the S-W group is not significantly different (at the $p < .05$ level) from its control. In short, in the other experimental groups, conditioning seems to have occurred.

Because of the desire to look at the associative aspects of the data, apart from those aspects which do not seem a function of the pairing of the stimuli, an adjustment procedure was devised and employed in an effort to isolate that portion of the results which were contributed by the actual pairing of the stimuli. This process consisted of deducting the mean of the appropriate control group performance over the last four trial blocks, from

TABLE IV

INDIVIDUAL COMPARISONS: EXPERIMENTAL VS. CONTROL

	W-W vs W+W	W-M vs W+M	W-S vs W+S	M-W vs M+W	M-M vs M+M	M-S vs M+S	S-W vs S+W	S-M vs S+M	S-S vs S+S
F-ratio	18.60 15.55	91.53 78.25	52.48 41.63	17.44 22.89	4.84 5.87	38.47 38.13	1.96 2.12	7.03 6.23	11.02 10.70
Level of Significance	$p<.01$	$p<.01$	$p<.01$	$p<.01$	$p<.05$	$p<.01$	Non-significant	$p<.05$	$p<.01$

experimental Ss data, allowed an assessment of the conditioning factor without destroying the estimate of within-Ss variability. The effect of this adjustment procedure on the experimental group performance may be seen in Table I, Figure 5, and Figure 6. The adjustment factors are shown in Table II.

The reader will recall that the W≠W, M≠M, and S≠S control groups were not found to be significantly different over the last four trial blocks. One reasonably may ask, then, why in the adjustment procedure the individual control group data was utilized, as opposed to a mean of several groups, for example. The answer is perhaps best seen in Figure 4. It is notable that because of the lack of independence among these groups the control groups tested clearly did not represent the extremes of the performance range. Had the analysis of all groups been conducted, disregarding their lack of independence, it seems likely a significant difference would have been detected.

A 3 X 3 (CS X UCS) analysis of variance was then performed over the adjusted experimental data. The results showed a significant CS main effect, $F(2, 99) = 4.86$, $p < .05$, and a marginally significant UCS main effect, $F(2, 99) = 2.46$, $p < .10$. Perhaps most important, however, was the fact that the CS intensity-performance relationship found significant was an inverse one.

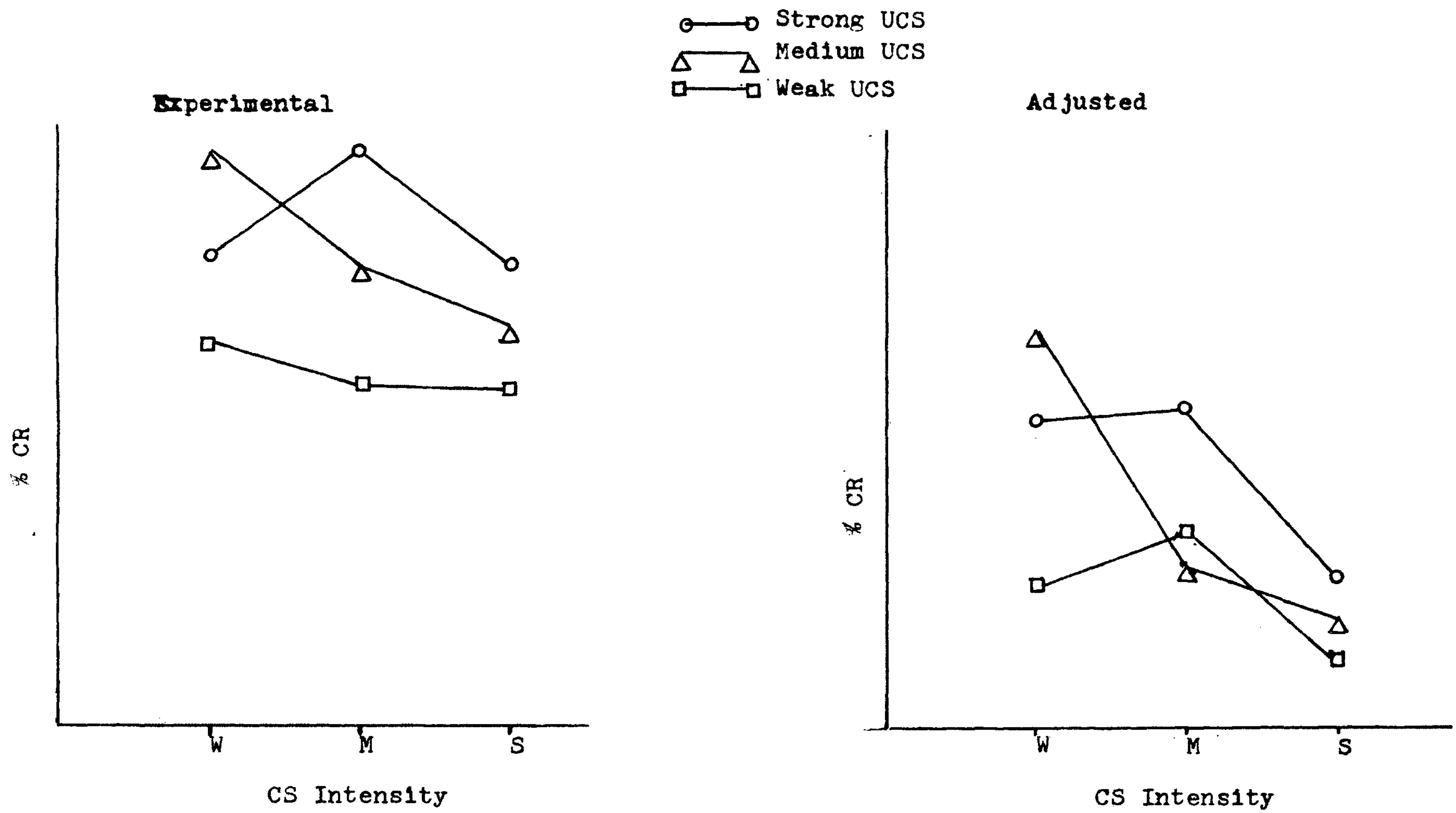

Fig. 5.-- UCS Intensity Effects on Performance as a Function of CS Intensity

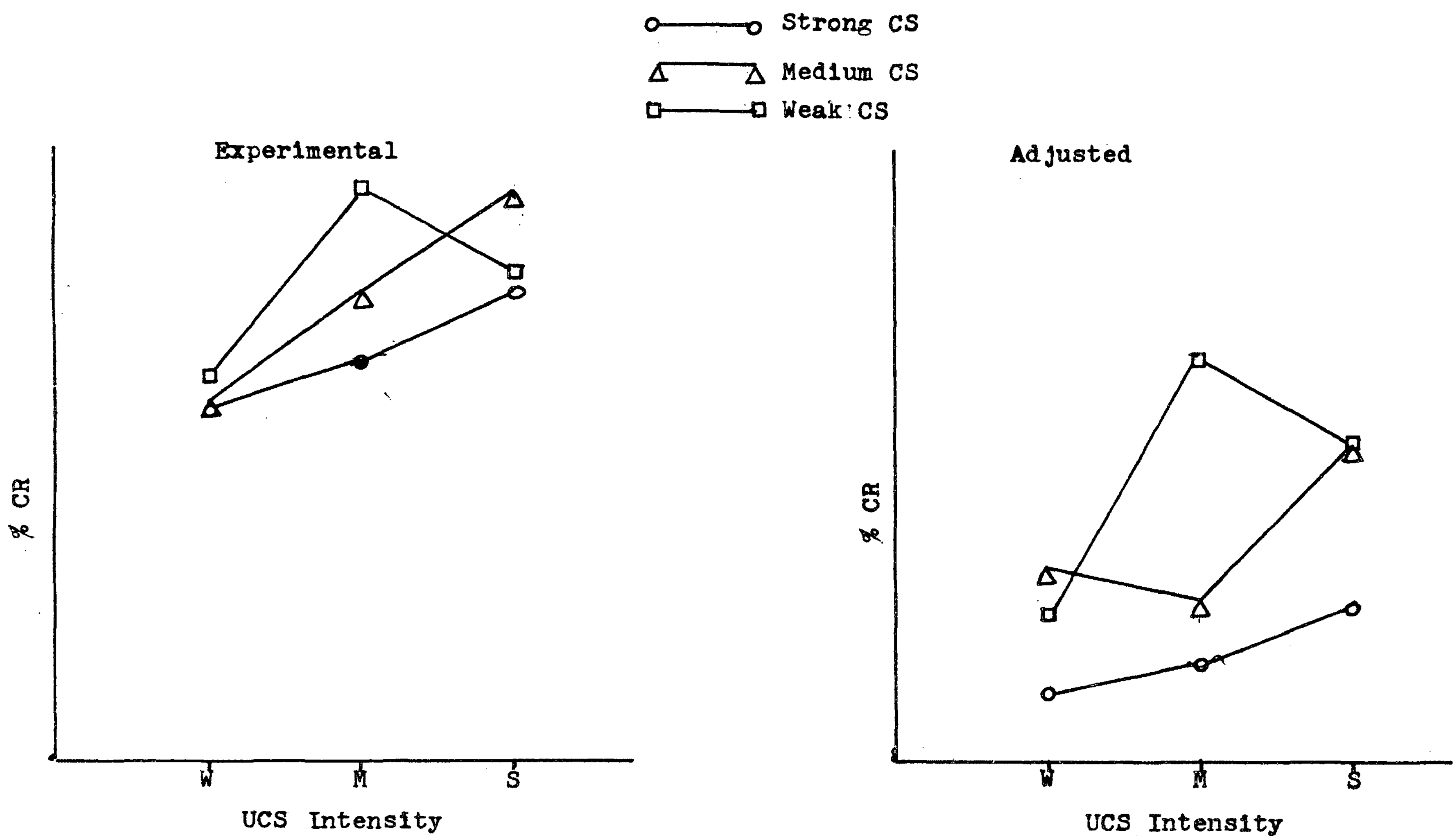

Fig. 6.-- CS Intensity Effects on Performance as a Function of UCS Intensity

Duncan's multiple range test was utilized to compare performance levels among the adjusted experimental groups. The significant ($p < .05$) individual comparisons are reported in Table V. Additionally, the adjusted groups were combined into groups of three on the basis of whether their stimuli were: (a) of the same intensity, (b) the CS was stronger than the UCS, or (c) the UCS was more intense than the CS. Again, using Duncan's multiple range statistic, the mean (over the last four trial blocks) of the CS dominant groups was found significantly ($p < .05$) inferior to the UCS dominant groups. The CS dominant groups were also marginally inferior to the mean of those groups with the same CS and UCS intensities ($p < .10$). Finally, the UCS dominant groups were not significantly superior to the groups with the same CS and UCS.

TABLE V

SIGNIFICANCE LEVELS OF INDIVIDUAL COMPARISONS BASED ON ADJUSTED DATA (DUNCAN'S MULTIPLE RANGE TEST)

	S-W	W-M	W-W	S-S	M-M	M-W	W-S	M-S	W-M
S-W	---	N.S.	N.S.	N.S.	N.S.	N.S.	.05	.05	.01
S-M		---	N.S.	N.S.	N.S.	N.S.	.10	.10	.05
W-W			---	N.S.	N.S.	N.S.	N.S.	N.S.	.05
S-S				---	N.S.	N.S.	N.S.	N.S.	.05
M-M					---	N.S.	N.S.	N.S.	.05
M-W						---	N.S.	N.S.	.10
W-S							---	N.S.	N.S.
M-S								---	N.S.
W-M									---

IV. DISCUSSION

Essentially, the questions posed by this study may be subsumed into two distinct parts. The first of these concerns the theoretical relevance of the results and the second, the generality of the findings to other more conventional conditioning techniques. Quite possibly these two questions are not unrelated and it is perhaps best to reserve judgment on the latter until the former has been examined.

With regard to the Hullian theoretical position, it seems fairly evident that little or no support is provided it by the results of the study. There appears in the overall analysis of both experimental and adjusted data a direct relationship between UCS intensity (Drive) and performance. On the question of CS intensity, however, there seems a fairly evident inverse CS relationship to acquisition performance which clearly poses problems if one holds to the Hullian notion of V, or stimulus intensity dynamism, as varying directly with CS intensity. Also the individual comparisons of performance among conditioning groups (see Table I) based on the adjusted data indicate that the S-S group was far from optimal relative to the other groups, another apparent violation of Hullian theory. The case may be seen somewhat more strongly when one notes that the acquisition of the W-M group was significantly ($p < .05$) greater than that of the S-S group (see Table V).

Adaptation level theory seems far better able to explain the results than does the Hullian position. The reader will recall that the reinforcement pooling model (Bevan, 1963b) leads one to expect that those groups in which the UCS departed farthest from the AL would achieve best performance. Necessarily, those groups in which the UCS is above the AL are also those groups which have UCS dominance, i.e., W-M, W-S, and M-S. Also according to this same formulation, the performance of S-S, M-M, and W-W, in which the UCS falls on or near the AL, would be superior to that of the aggregation with an inferior UCS, i.e., S-M, S-W, and M-W.

The results (based on the last four trials--adjusted) support the notion of these aggregates being ordered as AL theory predicts. Clearly the mean of the groups with CS dominance was found to be significantly inferior to that of either those groups with UCS dominance, or those with the same CS-UCS.

It is only within these aggregates that AL theory does not seem to offer excellent predictions. Looking at the mean response probabilities (see Table I), for neither the adjusted nor the simple data does the W-S group appear to have been the superior conditioning group, as AL would have predicted.

However, in keeping with the theory, S-W is the worst group for both sets of data. One is also struck by the remarkably similar levels attained by the S-S, M-M, and W-W groups on the adjusted data.

The reader is reminded that a psychophysical scaling procedure was utilized in an attempt to find the medium stimulus intensity which was perceived as being halfway between the strong (150 mm.) and weak (50 mm.) intensities. This medium (M) intensity stimulus allows another interesting prediction with regard to AL theory. It is that W-M and M-S should have achieved approximately the same levels of acquisition, as M-W and S-M should similarly have. With regard to the former pair, Table I shows fairly impressive evidence, particularly for the simple data, with response probabilities of .842 and .845 for W-M and M-S respectively. The evidence is somewhat less impressive for M-W and S-M, with probabilities of .525 and .579 reported, respectively.

The results are also somewhat in agreement with the Pavlovian position. Very obviously the need for UCS dominance, or as Pavlov termed it, a more "biologically significant" UCS seems fairly evident. Additionally

Pavlov's "Law of Strength" has provisions for the development of protective inhibition should the CS be made too strong. Pavlov's theory can then account for the inverse CS effect seen in Figure 6; however, it does not well explain the curvilinear function noted for the weak CS.

The theory, however, which seems best able to account for the results is that of Razran (1957), which essentially is a refinement and extension of the Pavlovian position. In his dominance-contiguity theory, Razran postulates some seven parameters which he says affect the course of CR acquisition. Of particular interest to this study is the third of these factors, that of a UR-magnitude CS-intensity ratio.

Razran says that it is imperative to examine the values of each variable into "comparisons of the conditionability of ascending or descending series of values of one variable at different fixed values of the other." He notes that the separate comparisons yielded CR efficacy curves which almost always included an ascending gradient followed by a descending one. Additionally found was that the higher the fixed values of the other variable, the further along in the series the reversal peak occurred. Finally he also noted that the higher the fixed values of the other variable, the higher was the CR-efficacy curve for the series.

Finally, Razran then notes that what he chooses to call the "empirics" of classical conditioning acquisition may be summarized into four statements:

(a) The acquisition of classical condition is essentially limited by two thresholds: an upper threshold of CS-intensity--the CS must not be too intense--and a lower threshold of UR-magnitude--the UR must not be too small.
(b) Within the thresholds, the efficacy of the acquisition varies directly with absolute values of UR-magnitudes and at first directly and then inversely with absolute values of CS-intensities (the inverse relationship occurring only at the upper segments of the CS-continuum).
(c) The efficacy of the acquisition varies also--and probably more significantly--with the ratios of the UR-CS values, there being by all signs an optimum UR-CS ratio (or ratios) at which classical CR acquisition is most efficacious while both below-optimal and above optimal ratios manifest decreasing effectiveness.
(d) The gradient of decreasing efficacies of above-optimal ratios appears in general to be considerably steeper than the corresponding below-optimal gradient.

In analyzing the extent to which Razran's theory fits the results of this study, it must be noted that for UR magnitude, UCS intensity (which is known to vary directly with UCR magnitude) must be substituted. Figure 5 and Figure 6 show the effect on acquisition for varying combinations of CS and UCS. In Figures 7 and 8, an attempt has been made to generate hypothetical CR-efficacy gradients which fit the experimental data as seen in Figures 5 and 6. It is possible to fit the data fairly

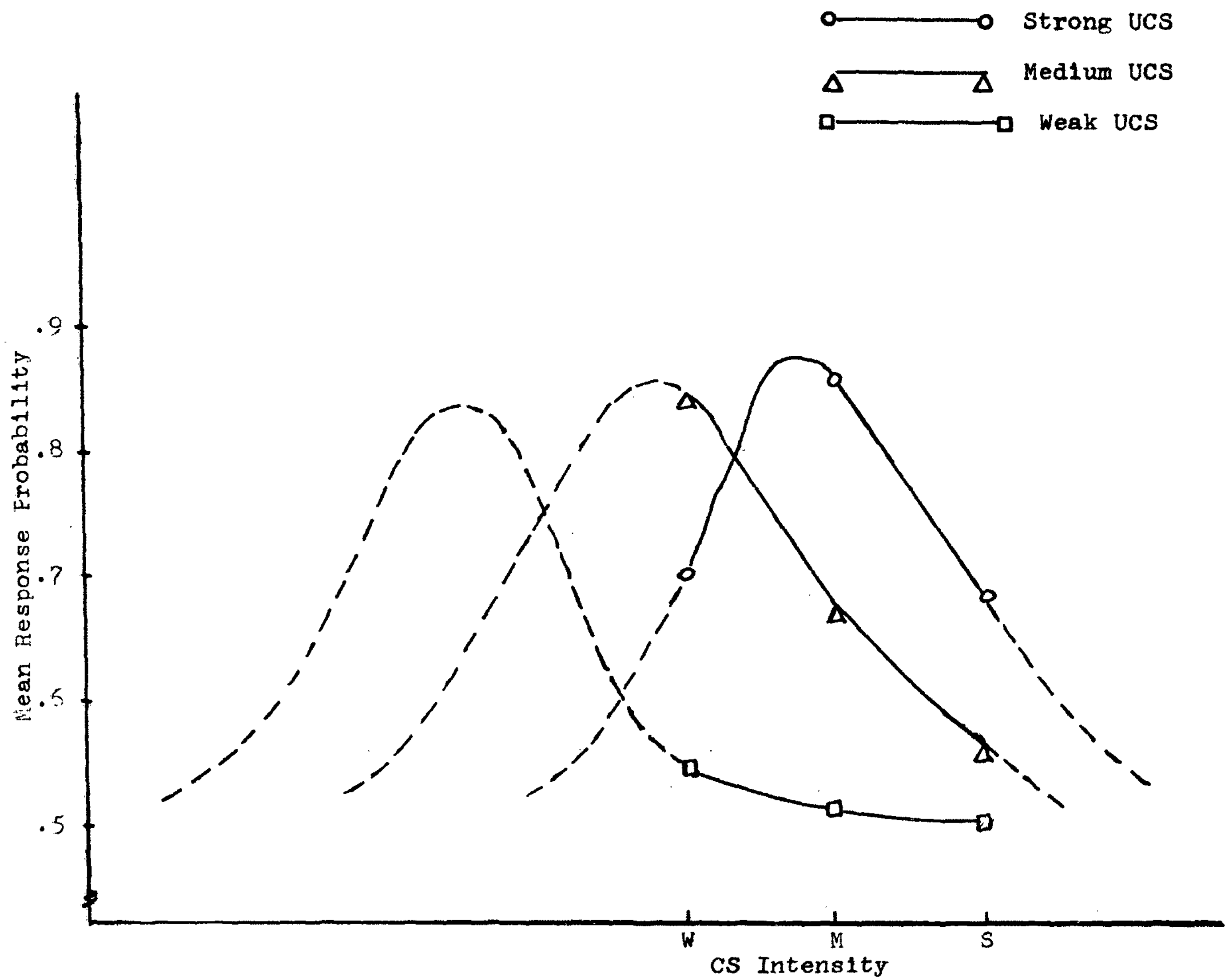

Fig. 7--Hypothesized Gradients for CR Efficacy (Based on non-adjusted percent CRs over the last four trial blocks)

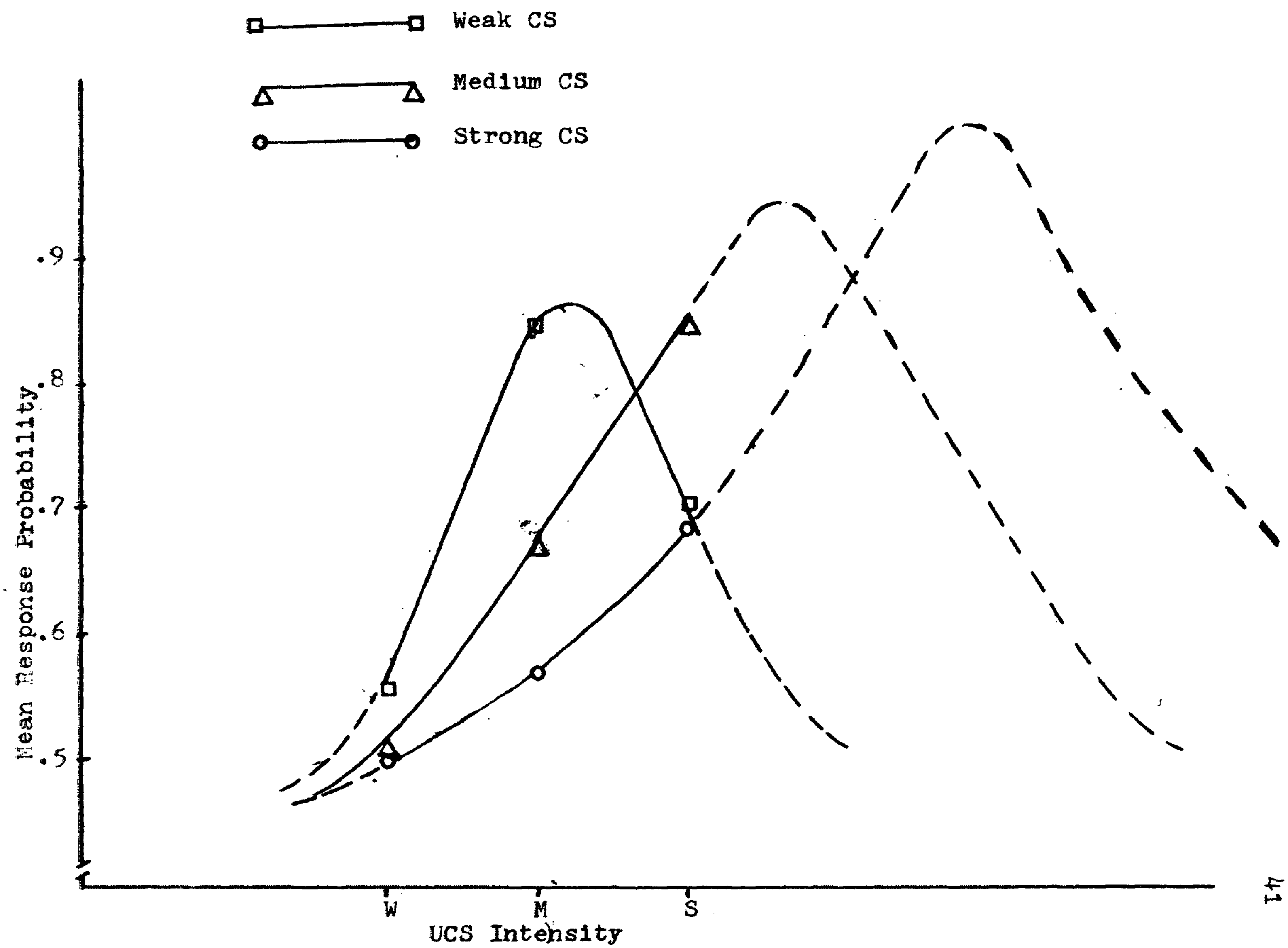

Fig. 8-- Hypothesized Gradients for CR Efficacy (Based on non-adjusted percent CRs over the last four trial blocks)

well for both increasing intensities of CS and UCS. It must be pointed out, however, that Razran does not specify definite parameters for these gradients and in fact states only some rather vague relations between them. Nonetheless, his theory does account for the curvilinear functions seen among the CS and UCS intensity curves. It is perhaps notable in these attempts to fit the results into the theory that in fact the apparent peak shifts in the gradients do occur later with increasing intensities and that for corresponding portions of the gradient, the levels of acquisition do seem to vary directly with the intensity of the series of stimuli.

Going on to the second of the questions originally posed, that of the generality of these findings, the one apparent discrepancy between this study and those using the more conventional light-puff or tone-puff pairings clearly seems to be that of the inverse CS relationship. It remains somewhat problematical whether the relationship was a function of the aversive character or the intensity of the CS. Certainly it seems logical to suppose that the CS stimuli in use here were appreciably more intense than those heretofore typically employed. If there is, in fact, a limiting factor beyond which increases in CS intensity induce such decrements, it seems quite tenable that this study has employed stimuli which exceeded it.

It is perhaps most notable that the CS effect was significant only in the adjusted experimental data. That is to say, before the non-associative factors were eliminated, the effect was not manifested.

Interestingly, Grice & Hunter (1964) showed that with a within-Ss design, CS effects were more likely to be detected. While Grice & Hunter seemed to imply these results were a function of the S experiencing both CS intensities, an alternate explanation might be advanced. In addition to allowing each S to experience both CS intensities, Grice & Hunter's within-Ss design also had the effect of holding constant, or controlling non-associative factors. This fact, coupled with the finding that adjusted data in the preceding between-Ss study yielded CS effects, leads one to the hypothesis that these non-associative factors may cause the masking of CS intensity effects. Admittedly, this hypothesis is a tenuous one, but seems worthy of further investigation.

Before leaving the subject of the inverse CS effect, it is worthy of note that this finding has precedence in conditioning research. Kimmel (1959) first noted that in conditioning the GSR (Galvanic Skin Response), tones more intense than 35 db yielded less conditioning. A similar result was again found in a later study (Kimmel, Hill, & Morrow, 1962) which reported best

GSR conditioning to a slightly supra-threshold stimulus (17 db).

The final argument which has bearing on the generality of the experimental findings concerns what might be termed the sensory adaptation hypothesis. Recalling that the CS and UCS are both delivered to the S's right cornea, one might contend that the differences in conditioning performance were merely a function of the temporary adaptation of the receptor organ. That is to say in the case of the S-M group, for example, the medium UCS was less effective than the same UCS in the W-M group, merely because the Ss in the S-M group did not perceive the second puff as being as intense. Thus, instead of the need for positing a CS-UCS optimal ratio, one might attempt to explain the data in terms of perceived UCS intensity.

The validity of this argument cannot be completely assessed at this time. There are, however, certain aspects of the data which seem to render the sensory adaptation notion unlikely. Looking at the data in Figure 5, one notices that the CS intensity has a somewhat differential effect which seems clearly to also be a function of the UCS intensity employed. It seems reasonable to suppose that if simple adaptation were occurring what should be seen would simply be three essentially parallel, descending linear functions (one for each UCS intensity). The data reveal this clearly not to be the case. The W-S group, in particular, and in fact the entire curvilinear form of the strong UCS function, seem to belie the sensory adaptation argument.

V. SUMMARY

One-hundred, eighty human Ss were run in an eyelid-conditioning study which employed as both the CS and UCS puffs of air delivered to the S's right cornea. The average CS was employed to provide a uni-modal dimension on which both CS and UCS intensities could be directly compared and varied, to determine their effects on conditioning performance. Nine conditioning groups were run, each of which received one combination of the nine possible weak, medium, or strong CS-UCS intensity pairings. Additionally, six pseudo-conditioning control groups were also run with those Ss receiving random, unpaired stimuli whose intensities corresponded to one of the experimental groups. Statistically significant differences were obtained between each conditioning group and its appropriate control, indicating that conditioning had occurred. Statistical significance was also found among the control groups and among the adjusted (experimental group minus control group) conditioning groups. Evidence is presented indicating the following relationships to hold between conditioning performance and these variables:

(a) UCS intensity seems directly related to conditioning performance.

(b) UCS dominance enhances conditioning.

(c) There is strong evidence that there exists an inverse relationship between CS intensity and acquisition of the CR.

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APPENDIX

PSYCHOPHYSICAL SCALING PILOT

Purpose

The following study was initiated in order to determine what physical intensity would be perceived as being exactly half way between the weak (50 mm. Hg.) and strong (150 mm. Hg.) puff intensities.

Subjects

Ten introductory psychology Ss were enlisted to participate.

Procedure

The Ss were read the following instructions:

> This experiment is designed to assess your ability to judge air puff intensities. You will receive puffs of air to your right eye. These you will be asked to rate along a numbered scale from "1" to "11," or from weakest to strongest. You will rate the same stimulus intensities several times.
>
> At regular intervals you will receive two reference stimuli--one very weak and representing a rating of "1" on the continuum below, and another very strong representing a rating of "11." All stimuli will be rated from "1" to "11" along the appropriate scale on the score sheet. The reference stimuli (the ones you use as a basis for your subsequent ratings) are already marked for you. These ratings appear on the first two scales of each score sheet. Your ratings for the subsequent stimuli should be made in the same manner--that is by placing an "X" over the appropriate score on the continuum. The experimenter will advise you when to turn the page of your score sheet. Remember, the first

> two stimuli received on each page are the reference stimuli (as indicated by Trials No. 1 and No. 2) and these are already rated for you. You will begin scoring the third stimulus delivered on each new rating sheet.
>
> The order of presentation of the stimuli is varied randomly, so your rating will not appear related in any systematic fashion. It is important that your eye be open when the puff is delivered. To warn you of the approach of each puff the red light in front of you will be turned on shortly before the puff is received. We suggest you blink when the light comes on and then try to hold your eye open so you can better judge the intensity of the air puff. You will have approximately 10 sec. to record your rating before the next stimulus is delivered. No changes should be made after you have marked your rating. It is realized your first ratings may be somewhat inaccurate; however, after you have become more familiar with the stimuli your accuracy will improve. Please do not lean your head back against the wall and do not communicate with the other subject.

The subjects were given a booklet comprised of seven rating sheets, each with 14 numbered scales on them (see Figure 10). The first two continua on each sheet were already marked for the S and were the reference stimuli, which served as the bases for the 12 subsequent ratings.

Nine different stimulus intensities were administered ranging from 50 mm. Hg. to 150 mm. Hg. at increments of 12½ mm. Hg. The extreme intensities served as the referents. After the two reference stimuli were delivered, a random sequence of the intermediate intensities was presented at intervals of about 10 sec. All nine stimuli were then delivered and three (randomly selected) were repeated during each rating period. The Ss were then advised to turn to the next page of their rating booklet, and the procedure was repeated beginning again with the reference intensities.

Each rating sheet provided one estimate (a number from "1" to "11") of the intensity of the nine stimuli. Thus seven estimates were obtained for each intensity from each S. The mean ratings for each intensity were then computed thereby making possible the formulation of a psychophysical function (see Figure 9) relating perceived intensity and physical intensity. A process of interpolation determined that the physical intensity which corresponded to the rating of "6" was one of 105 mm. of Hg. This stimulus was used as the medium (M) intensity in the principal experiment. See Torgerson (1958) for an elaboration of the technique of subjective estimation used in this experiment.

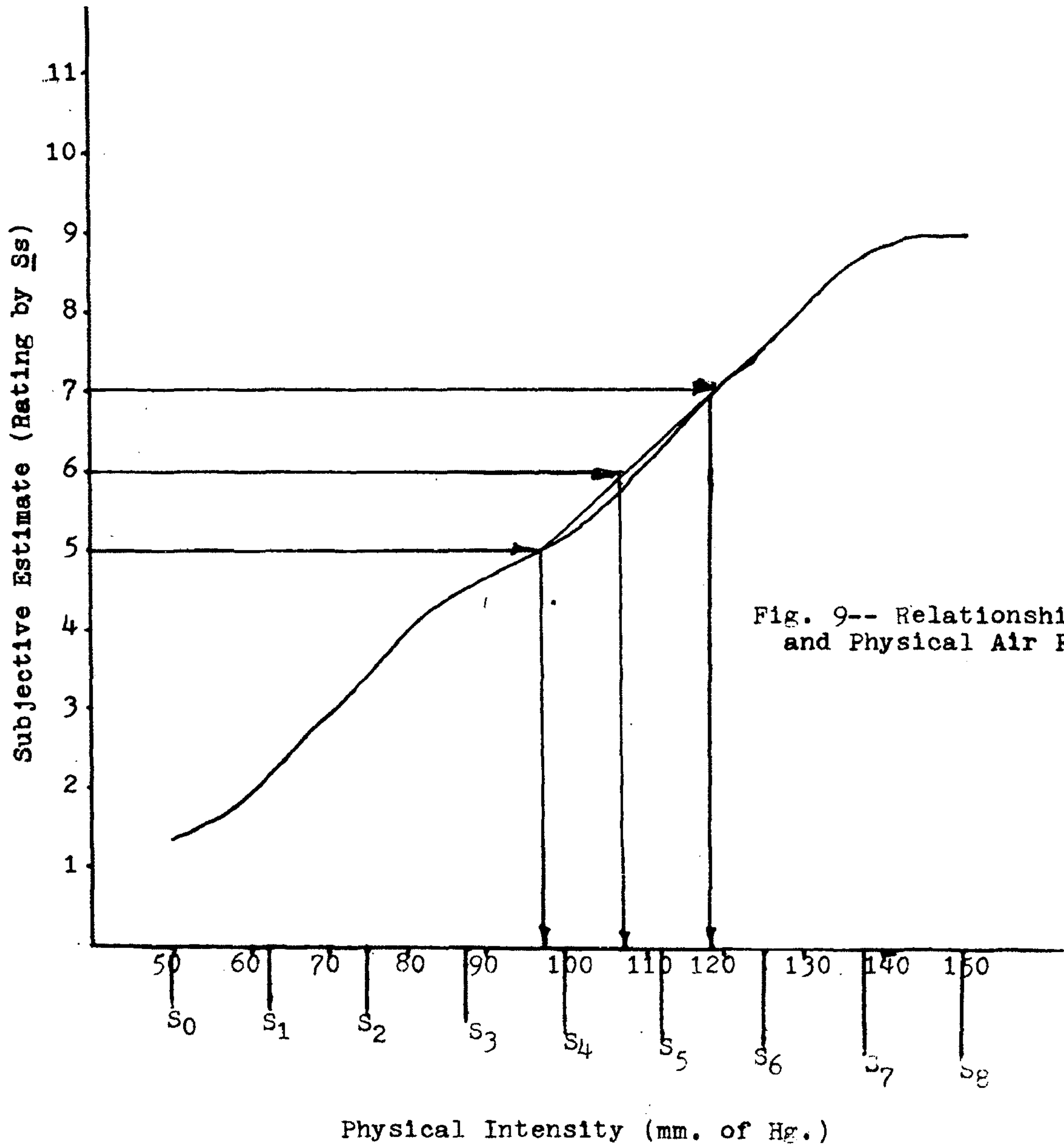

Fig. 9-- Relationship: Perceived and Physical Air Puff Intensities

Subject No. _____

Sex _____

	Weak					Medium					Strong
Trial No. 1	1	2	3	4	5	6	7	8	9	10	11
Trial No. 2	1	2	3	4	5	6	7	8	9	10	11
Trial No. 3	1	2	3	4	5	6	7	8	9	10	11
Trial No. 4	1	2	3	4	5	6	7	8	9	10	11
Trial No. 5	1	2	3	4	5	6	7	8	9	10	11
Trial No. 6	1	2	3	4	5	6	7	8	9	10	11
Trial No. 7	1	2	3	4	5	6	7	8	9	10	11
Trial No. 8	1	2	3	4	5	6	7	8	9	10	11
Trial No. 9	1	2	3	4	5	6	7	8	9	10	11
Trial No. 10	1	2	3	4	5	6	7	8	9	10	11
Trial No. 11	1	2	3	4	5	6	7	8	9	10	11
Trial No. 12	1	2	3	4	5	6	7	8	9	10	11
Trial No. 13	1	2	3	4	5	6	7	8	9	10	11
Trial No. 14	1	2	3	4	5	6	7	8	9	10	11

Figure 10. Sample scoring sheet.